The Acorn and Beechnut Fields, Blocks 29/8a(S), 29/8b, 29/9a(S) and 29/9b, UK North Sea

F. Hagen[1], J.G.Gluyas[1,2] and G. Goffey[3]

[1]Earth Sciences Department, Durham University, DH1 3LE, United Kingdom

[2]Durham Energy Institute, Durham University, DH1 3LE, United Kingdom

[3]Soliton Resources Limited, Twickenham, TW1 2QU, United Kingdom
Correspondence: frances.m.hagen@durham.ac.uk

accepted 16th November 2018

Abstract

Unocal discovered the Acorn South Field with wells 29/8b-2 and 29/8b-2s in 1983. The well and its side-track found a small accumulation of oil in Upper Jurassic, Fulmar Formation sandstones in an inter-pod setting. Well 29/8b-3 drilled two years later on what was thought to be the same structure found Acorn North, a larger accumulation of oil in a Triassic Skagerrak Formation reservoir on the crest of a Triassic pod. Premier discovered the Beechnut Field two years later, well 29/9b-2 finding oil in the Fulmar and Skagerrak Formations in a faulted, inter-pod setting. Both Acorn and Beechnut are deep, high pressure and high temperature fields with complex reservoir stratigraphy due to halokenesis during sedimentation and post-depositional structuration. The Skagerrak Fm. reservoir in Acorn North is appreciably poorer and than similar age reservoirs further north whilst the Fulmar Fm. in Beechnut is relatively poorly developed.

Acorn's mid case oil in place is 90 MMbo in the Skagerrak Formation and 13 MMbo in the Fulmar Formation and for Beechnut is 15 MMbo in the Fulmar Fm. Neither field has been developed. Limiting factors include the resource size, variable reservoir development (Beechnut), modest reservoir quality (Acorn North), compartmentalisation concerns and development costs.

Keywords: Acorn, Beechnut, Fulmar, Skaggerak, pod, inter-pod

The Acorn and Beechnut oilfields lie in Blocks 29/8 and 29/9 in the northern half of Quad 29 of the UK Central North Sea (Figure 1) and on the western margin of the high pressure, high temperature (HPHT) province. Each contains oil in Triassic Skagerrak Fm. and Upper Fulmar Fm. sandstones. The presence of oil contrasts with the condensate found nearby in similar age reservoirs in the Puffin, Franklin, Elgin and Glenelg fields. Both Acorn and Beechnut were discovered in the mid-1980's and have had between them eight different operators. The last appraisal well was drilled on Acorn in 2009, 26 years after the field was discovered. Shell, the most recent operator of both fields, relinquished the acreage in 2015 (Shell, 2015) and both fields are now unlicensed.

The reservoir geology within both the Triassic Skagerrak Fm. and Upper Jurassic Fulmar Fm. sandstones is complex, having been affected by both syn-depositional and post-depositional movement of the underlying Upper Permian Zechstein Gp. halite (Smith et al, 1993). Both reservoir intervals have tested at high oil rate but flow rates tend to diminish rapidly because of compartmentalisation.

History of Exploration and Appraisal

The first well drilled on the two blocks was 29/8b-1 by Premier Oil in 1976. It is not clear what was the target, although by analogy with operators in the same area it would seem likely that Premier hoped to discover oil in the Upper Jurassic Fulmar Fm., however the well was abandoned as dry. It encountered Lower Cretaceous mudstones with a conglomeratic base at 11,160 ft MD resting on red-brown Triassic mudstones; the whole of the Jurassic section and the Triassic reservoir sections were absent. Below the Triassic the well penetrated a thin Zechstein Gp. section and a sandstone-prone Rotliegend Gp. sequence with oil shows in the top 32 ft.

In 1983, Acorn field wells 29/8b-2 and 29/8b-2s (Acorn South) were drilled by Union Oil, discovering oil in Upper Jurassic, Fulmar Fm. sandstone (Table 1). Shell/Esso drilled 29/8a-3 on what was thought to be the same structural closure in 1985, this time however oil was discovered in the Triassic Skagerrak Fm. sandstone (Acorn North). The well tested at 4,500 bopd (Venture, 2010) and with a reservoir pressure of 10,997 psia and temperature of 160° C, is categorised as HPHT. Acorn North was appraised by well 29/8a-6 in 2009, which conducted an extended well test in a horizontal penetration in the Triassic Skagerrak Formation. The initial well test rate declined to 5,000 bopd after the withdrawal of some 52,000 barrels from the reservoir.

In the same year that Acorn was discovered, Premier made the Beechnut East discovery with well 29/9b-2, which tested oil under HPHT conditions from Fulmar, Lower Jurassic Pentland and Skagerrak Fm. sandstones at a maximum combined rate of 7,425 bopd. Four further appraisal wells were drilled on the Beechnut Field between 1989 and 2001 proving three separate accumulations (Table 1). In 1988 Shell/Esso drilled 29/8a-4 into a separate structure to the north west of Acorn and discovered oil in Jurassic Pentland and Triassic Skagerrak Fm. sandstones (Lyyn North).

Well	Well type	Date	Operator	Oil?	Reservoir Formation	Fm./Gp. at total depth	Test rate (bopd)	Pressure (psia)	Datum (ft TVDSS)
29/8b-1	Exploration	1976	Premier	dry	-	Rotliegend	-	-	-
29/8b-2 29/8b-2s	Exploration Acorn South	1983	Union	yes	Fulmar	Smith Bank	-	-	-
29/8a-3	Exploration Acorn North	1985	Shell	yes	Skagerrak	Smith Bank	4,500	10,997	13,200
29/9b-2	Exploration Beechnut E	1985	Premier	yes	Fulmar & Skagerrak	Skagerrak	7,266	11,040	13,800
29/9b-3	Exploration	1986	Premier	dry	-	Rattray	-	-	-
29/8a-4	Exploration Lynn North	1988	Shell	yes	Pentland & Skagerrak	Skagerrak	Oil and water at low rates	-	-
29/9b-6	Appraisal Beechnut	1989	Premier	yes	Fulmar	Zechstein	1,203	11,231	13,800
29/9c-8	Appraisal Beechnut	1992	BG	dry	Skagerrak (Fulmar absent)	Skagerrak	-	-	-
29/8b-5	Exploration	1996	Hess	dry	-	Skagerrak	-	-	-
29/9b-9	Appraisal Beechnut	2001	Hess	yes	Fulmar	Zechstein	2,434	10,625	13,800
29/9b-9z	Appraisal Beechnut	2001	Hess	yes	Fulmar (attenuated)	Rattray	Oil sample	11,130	13,800
29/8a-6	Appraisal Acorn	2009	Venture/ Centrica	yes	Skagerrak	Skagerrak	EWT 5-6,000	-	-

Table 1 Exploration and appraisal wells on Blocks 29/8 and 29/9 including the Acorn and Beechnut fields

Development

To date, operators have not identified economic development schemes for Acorn and/or Beechnut. Limiting factors include the poorly connected nature of the Acorn Skagerrak Fm. reservoir, variable development and compartmentalisation of the Beechnut Fulmar Fm. reservoir, the limited scale of recoverable resources, particularly at Beechnut, development cost and the wax content of the crude oil. Shell evaluated both fields as a combined subsea tie back to Puffin Field or to the planned floating production and storage vessel that was to have been used in the development of the adjacent Fram oil and gas field (Figure 1). However, disappointing early development drilling on Fram Field led to the decision to develop only its gas resource as a subsea tieback to Shearwater Field. This meant that the nearest host for Acorn/Beechnut would have been the more distant Shearwater facility and a tieback of this type was deemed uneconomic. The fields remain undeveloped.

Regional Context

The oldest strata penetrated in northern Quad 29 are of Permian age and there is a near complete stratigraphic column to and including the Pliocene (Figure 2). Only sediments deposited during Early Jurassic times are absent from the region.

The Permian Rotliegend Gp. clastic interval is overlain by the Zechstein Gp. evaporite sequence which is reported by Porter et al (2015) to be commonly in excess of 1000m thick, though it seems probable that such thicknesses are a result of halokeneis rather than depositional thicknesses. Extension during the Triassic led to the formation of SSE-NNW orientated main basement faults, which in turn generated a series of large north-westerly trending sedimentary basins. Loading of the Zechstein salt led to the development of so-called ‘pods’ of Triassic sediment, mainly Smith Bank Fm., which accumulated due to salt withdrawal into adjacent salt walls and diapirs (Figure 3; Hodgson et al 1992). The location of salt diapirs and swells was influenced by the distribution of underlying fault blocks.

Strata belonging to the Lower Jurassic are little known from the area that was affected by Jurassic thermal doming (Underhill and Partington, 1986). Lower Jurassic strata have been reported in 29/9b-2 but it is more likely the strata belong to the Middle Jurassic Pentland Formation. Middle Jurassic volcanic deposits of the Rattray Formation and paralic sediments of the Pentland Formation accumulated in the area. The Upper Jurassic section comprises of a combination of marine sandstones belonging to the Fulmar Formation and the overlying mudstone interval that includes the Heather Formation and Kimmeridge Clay Formation oil source rock. Upper Jurassic sediments rest unconformably on Triassic or Middle Jurassic sediments/volcanics.

As a consequence of salt withdrawal/collapse triggered by Jurassic extension, Middle and Upper Jurassic sediments tend to be localised in ‘inter-pod’ settings on top of salt diapirs and salt walls whilst some of the adjacent Triassic ‘pods’ became local highs as underlying salt withdrawal led to their grounding on pre-Zechstein strata via basal salt welds (Figure 3). In consequence the thickness of Upper Jurassic sediment commonly correlates negatively with the thickness of Triassic sediment (Figure 3). The extent of salt movement is evident on a top Zechstein map (Figure 4) and the influence of the salt movement on configuration of the Base Cretaceous Unconformity (BCU) is clearly evident (Figure 5). Understanding the distribution of these ‘pod’ and ‘inter-pod’ strata is critical in the Acorn/Beechnut area as it provides the basis for prediction of Jurassic and Triassic reservoir presence.

Database

Several seismic surveys have been acquired across Blocks 29/8a and 29/9b and data used by Porter et al (2015) in evaluating Acorn and Beechnut are shown in Table 2 and Figure 1.

<table>
<tr><th>Year acquired</th><th>Type</th><th>Processing</th><th>Area covered</th><th>Acquisition orientation</th><th>Angle stacks</th></tr>
<tr><td>1999</td><td>Conventional</td><td>2010-11 PSTM</td><td>All</td><td>North-south</td><td>Yes</td></tr>
<tr><td rowspan="2">2004</td><td rowspan="2">Conventional</td><td>2011 HPHT PSDM</td><td>All</td><td rowspan="2">North-south</td><td rowspan="2">Yes</td></tr>
<tr><td>2014 CGG PSDM</td><td>All</td></tr>
<tr><td rowspan="2">2014</td><td rowspan="2">Broadseis</td><td>2014 CGG PSTM</td><td>Acorn only</td><td rowspan="2">West-east</td><td rowspan="2">No</td></tr>
<tr><td>2014 CGG PSDM</td><td>Acorn only</td></tr>
</table>

Table 2 seismic data coverage for Acorn and Beechnut (PSTM denotes pre-stack time migration, PSDM denotes pre-stack depth migration)

Wireline or logging while drilling (LWD) log data suites (gamma, sonic, density and resistivity) were acquired in all wells. Repeat formation tester (RFT) data were collected from 29/8a-3 while PVT data were acquired from fluids sampled in Acorn well 29/8b-2 and Beechnut well 29/9b-9 although it is not clear from either Venture (2010) or Porter et al (2015) whether other data were obtained from Beechnut wells. Core was acquired from the Skagerrak Formation in Acorn well 29/8-3 and core from nearby wells 29/3b-4, 29/5b-7 were used to supplement the limited wireline and core data available from Acorn itself. Core data were acquired from the Fulmar Formation in all of the Beechnut wells.

In addition to routine core analysis data, special core analysis data were obtained from the core taken in 29/8a-3, including formation resistivity and resistivity index, formation factor as a function of overburden pressure, air-brine capillary pressure, mercury injection (drainage and imbibition), porosity as a function of overburden pressure and cation exchange capacity.

Trap

The trapping geometry of the Acorn Field is a dip-closed dome with several subordinate crests with similar elevations (Figure 6). The main accumulation, Acorn North, is a relatively simple, N-S oriented crest of a Triassic pod with Skagerrak Fm. reservoir in the upper portion of the pod, overlain (most likely unconformably) by Jurassic Heather Fm. (Figure 7). However, Acorn is not a typical Triassic pod as the overall structure is influenced by the presence of an underlying salt pillow and two small salt diapirs within Acorn North as well as a major salt diapir underpinning Acorn South (Figure 4), which broadly occupies an inter-pod setting. The reservoir is faulted and displacements are small but may be significant in terms of potential compartmentalisation. Topseal is provided by Upper Jurassic Heather Fm. mudstones and where these are absent by Kimmeridge Clay Fm. The majority of Acorn North displays a seismic character indicative of the presence of Skagerrak Fm. sandstones with thin Jurassic cover, although fringing areas and downthrown blocks may contain an expanded Jurassic section.

The Beechnut Field trap is essentially a faulted E-W oriented anticline with overall four-way structural closure (Figure 8). It is an inter-pod setting, underpinned by an E-W oriented Zechstein salt wall and separated from the Acorn South salt diapir by a Triassic pod (Figures 9 and 10). Uplift and erosion post deposition of the Fulmar Fm. mean that the reservoir is truncated on top of the Triassic pods surrounding Beechnut and stratigraphic trapping is required for the undrilled Beechnut South prospect. Most of the reservoir structuration is Late Jurassic to Early Cretaceous in age, with minor Cimmerian inversion. Beechnut is compartmentalised by multiple E-W oriented faults and three of the fault blocks contain hydrocarbons; Beechnut East (29/9b-2), the tiny Beechnut B6 block (29/9b-6) and the downthrown Beechnut South Flank Graben (29/9b-9). Pressure data from the wells indicates that the various fault blocks in Beechnut are at different overpressures. These data are taken to indicate that the field is divided into fault-sealed compartments. The different geochemical signatures of oils in each fault block support such an interpretation.

Reservoir and Petrophysics

Acorn North Field

The Triassic Skagerrak Fm. reservoir of Acorn North typically comprises very fine to fine-grained sandstones organised into 1-4m thick units, fining-upwards from mudclast-bearing, cross-bedded and planar-bedded sandstones to heterolithic sandstones and laminated siltstones. These are interpreted to have been deposited as channel sandstones and thalweg deposits during ephemeral periods of fluvial activity in a semi-arid, dryland setting. Non-reservoir, mudstone-prone lithologies are interpreted to be unconfined splays and playa-lake deposits. Sparse biostratigraphic data establish the upper part of the Skagerrak Fm. section as being Early Ladinian in age, indicating the bulk of the penetrated section is likely to be the Judy Sandstone Member (Shell, 2015).

The Skagerrak interval in Acorn is comparable to that described in detail by McKie and Audretsch (2005) in the Heron cluster (Heron, Egret, Skua and Seagull fields) some 50km to the north, however the Acorn area has a lower net to gross ratio than seen in the Heron cluster. The proportion of channel belt deposits is lower, grain size tends to be finer and channel fill sequences more heterolithic than to the north, leading to the interpreted loss of high permeability, well connected reservoir at Acorn compared to the Heron area. As a consequence, reservoir connectivity at Acorn is anticipated to be appreciably worse than in the Heron area.

Porosity and permeability data from Acorn well 29/8a-3 are shown in Figure 11a. The average core porosity is 17% for the whole interval and 18% for the sandstones above the oil water contact. Average air permeability for the sandstones is 8.4 mD (geometric mean). Petrophysical analysis of the Skagerrak Fm. in Acorn North is aggravated by differing log suites between the two wells and the absence of a water sample to constrain water salinity. Salinity was initially estimated from logs in the water leg to range upto 250,000 ppm NaCl, however in the best reservoir intervals a salinity of 80,000 ppm NaCl is computed and was used for the petrophysical analysis summarised in Table 3, below.

Well	Gross	Net	Not Net	Unknown	Net to Gross	Net to (Gross-Unknown)	Facies	Av Porosity	Av Permeability	Av Hydrocarbon Saturation Log	Av Hydrocarbon saturation SHF
29_8A-3	82	0	82	0	0.00	0.00	0				
29_8A-3	210	195	15	0	0.93	0.93	1	0.16	6.4	0.30	0.46
29_8A-3	74	74	0	0	1.00	1.00	2	0.23	105	0.49	0.62
29_8A-6	160	0	160	0	0.00	0.00	0				
29_8A-6	169	125	45	0	0.74	0.74	1	0.15	4.1	0.42	0.44
29_8A-6	27	27	0	0	1.00	1.00	2	0.21	48	0.61	0.68

Table 3. Petrophysical analysis results of the oil legs in wells 29/8a-3 and 29/8a-6 (thickness in TVD, porosity cutoff 10.6%, SHF denotes saturation-height function and the facies column denotes log facies where 0 is non reservoir, 1 is reservoir below 20mD and 2 is reservoir above 20 mD) (Porter et al 2015).

RFT and log data do not allow precise assessment of fluid contacts in 29/8a-3 consequently oil staining was used as the basis for assessment of an oil-down-to level at 13,212 ft TVDSS and water-up-to level at 13,245 ft TVDSS. A free water level was estimated at 13,228 ft TVDSS, being the base of DST 1 which flowed no water.

Beechnut Field

The Upper Jurassic Fulmar Formation at Beechnut is unlike that encountered elsewhere in the Central North Sea insofar as it is not a field-wide, thick, medium grained, marine sandstone (Jeremiah and Nicholson, 1999). Beechnut occupies an inter-pod setting and structurally elevated well 29/9b-2 has the most complete section of Fulmar Fm. In this well the Fulmar Fm. is split into a lower, cleaner unit of fine to medium grained, well sorted, pyritic and glauconitic sandstone and an upper unit of very fine to fine grained, variably argillaceous sandstone with interbedded claystone and siltstone in an overall fining-upwards package. These two intervals are recognised in other Beechnut wells and are interpreted as marine sandstones, comprising a lower 'pre-rift' package of shoreface/shelfal sands and an upper, 'syn-rift' package recording progressively increasing shelfal water depths and truncated by the Volgian unconformity.

Core data from Beechnut wells (Figure 11b) shows permeability values ranging up to c. 100 mD with porosity values up to c. 26%. The lower unit displays the best reservoir quality (Table 4). Deposition is thought to have occurred as a shallow marine fringe around former Kimmeridgian structural highs, with preservation of those sandstones affected by subsequent erosional truncation during Volgian extension (Figure 11). Reservoir quality may have been controlled by sedimentation rate; slow subsidence leading to condensed, sand-prone deposition, rapid subsidence leading to expanded, shale-prone deposition. For example, despite having one of the thickest Upper Jurassic intervals in the local area, the 29/9b-3 well was mudstone-prone throughout (Figure 12).

Modelling shows that seismic amplitude at the top of the pre-rift package can be related to reservoir quality and this relationship is used to map areas of pre-rift reservoir development within the field. Patchy seismic amplitude development suggests variable reservoir distribution and coupled with the well penetrations indicates a thin, heterogeneous reservoir system.

Well	**Package**	**Gross ft**	**Net ft**	**N:G %**	**Ave. porosity %**	**Ave. Vclay %**	**Ave. Sw %**
29/9b-2	Syn-rift	115	28	24	11.1	30	38
	Pre-rift	83	77	92	18.3	13	19

29/9b-6	Syn-rift	51	0	0	-	-	-
	Pre-rift	31	26	83	16.6	24	31
29/9b-9	Syn-rift						
	Pre-rift	156	69	44	13.4	23	49

Table 4 Fulmar Fm. petrophysical analysis results from wells 29/9b-2 and 29/9b-6 (cutoffs <55% clay volume and > 10% porosity). Note there are suggestions that the Fulmar Fm. reservoir may be partially faulted out in well 29/9b-6 (Venture, 2010).

No oil-water contact has been penetrated in the Fulmar Fm. reservoir. Pressure data from Beechnut wells suggest that the reservoir interval is compartmentalised (Figure 13), with different pressure regimes in each well. It is perhaps a surprise that the Fulmar Sandstone in well 29/9b-2 at 13,200 ft appears to be in pressure communication with the Pentland/Gassum Formation some 700 ft deeper in the same well, however geochemical and PVT evidence supports a single oil column of at least 727 ft to an oil-down-to level of 13,942 ft TVDSS (Venture, 2010). Both these Jurassic oil occurrences are pressure separated from the short oil column found in the Triassic section of the same well.

Production history and resources

Neither the Acorn nor the Beechnut Field have been developed.

The estimated mid case, discovered stock tank oil originally in place (STOOIP) for Acorn North is 90 MMbo in the Skagerrak Formation with an estimated 12 MMbo recoverable from a multi-well development (Shell, 2015). A STOOIP of 13 MMbo is estimated for the Fulmar Fm. in Acorn South (Venture, 2010). Beechnut has an estimated STOOIP of 1 to 13 MMbo in the area tested by wells 29/9b-2 and 29/9b-6, 6 to 13 MMbo in the segment tested by 29/9b-9 and 1 to 38 MMbo in an untested southerly segment (Porter et al, 2015). Higher STOOIP estimates of c. 50 MMbo and 60 MMbo respectively are also in the public domain (Venture 2010). The latter volume includes the southerly segment and it is acknowledged that further drilling is required. Other than Acorn North, recoverable resource volumes for the discovered fields are *de minimus* (Shell, 2015).

Well test rates obtained during the appraisal drilling programme are given in Table 1. At Acorn Field, the 29/8a-3 drill stem test was of insufficient duration to resolve long term productivity of the reservoir, in particular connectivity to reservoir volume away from the wellbore area. The 29/8a-6 extended well test withdrew 52,000 barrels from a 600 ft MD penetration of the reservoir over a 10 day period. This was followed by a 70 day shut-in period in which pressure build-up was measured but the reservoir had not returned to initial pressures by the end of the build-up period. Inflow was from three main zones which displayed the best reservoir quality in channel sandstone facies but comprise only c. 10% of the reservoir. Pressure analysis indicated that the well is connected to a limited volume with slow feed from a distant, larger volume, which is consistent with the depositional model. This result was not encouraging for reservoir connectivity and did not support further progress towards full field development.

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Acknowledgements

Much of the data in this paper is based upon a Shell internal report (now released) from May 2015 entitled 'Acorn and Beechnut integrated subsurface report' by Michael Porter, Andrew Lightfoot, Peter Mohr and Lorraine Maan-Beck. These authors are thanked. Without their report and its release by Shell, this paper would not have been possible. Common Data Access provided the data for exploration wells 29/8b-1 and 29/8b-5 and are thanked accordingly.

Figure captions

Figure 1 Location map for the Acorn and Beechnut fields. The area lies about 200 km east of Aberdeen in the Central North Sea high-pressure, high-temperature province. The red box shows the area of coverage of 2004 3D data whilst the blue box shows that of the 2014 3D data (refer to Table 2).

Figure 2 Stratigraphy of the Acorn-Beechnut area (Venture, 2010).

Figure 3 Schematic north-south cross section through Beechnut field and adjacent areas showing the distribution of mobile salt and intervening areas of Triassic strata and Jurassic overburden (from Shell, 2015). Sm Bnk denotes Triassic Smith Bank Fm., Skg denotes Triassic Skagerrak Fm., RotlG denotes Permian Rotliegend Gp.

Figure 4 Top Zechstein Gp. regional two way time structure as interpreted using the 2011 HPHT dataset (Shell, 2015). The most prominent salt diapir is the Fram diapir whilst the less prominent salt features to the south underlie the Acorn Field.

Figure 5 Regional two way time structure on the Base Cretaceous Unconformity as interpreted using the 2011 HPHT dataset (Shell, 2015).

Figure 6 Acorn North Top Skagerrak Formation depth structure map (Shell, 2015). Oil-down-to level shown by solid green line. Contour interval 50 feet.

Figure 7 Acorn North representative, W-E seismic line (Shell, 2015). Black peak is negative acoustic impedance, inset shows location of line.

Figure 8 Beechnut Top Upper Jurassic Fulmar Formation depth structure (Shell, 2015). Discovered accumulations are shown in orange, undrilled prospects in buff.

Figure 9 Beechnut representative, S-N seismic line (Shell, 2015).

Figure 10 Variance time slice superimposed on Base Upper Jurassic two way time structure (red/yellow indicates high, contour interval 50 ms). The edge of the mapped base Upper Jurassic represents the interpreted maximum extent of Fulmar Fm. at its erosional limit.

Figure 11a. Porosity and permeability data from the cored Skagerrak Fm. in Acorn well 29/8a-3, coded by interpreted depositional facies. 11b. Porosity and permeability data for the cored interval in Beechnut Field wells 29/9b-2, 29/9b-6 and 29/9b-9 (Venture, 2010).

Figure 12 Correlation of Upper Jurassic strata including the Fulmar Formation sandstones in Beechnut Field and adjacent areas using gamma-ray versus neutron and density logs (Shell, 2015).

Figure 13 Beechnut Field reservoir pressure/depth plot (Venture, 2010).

Field Summary Table

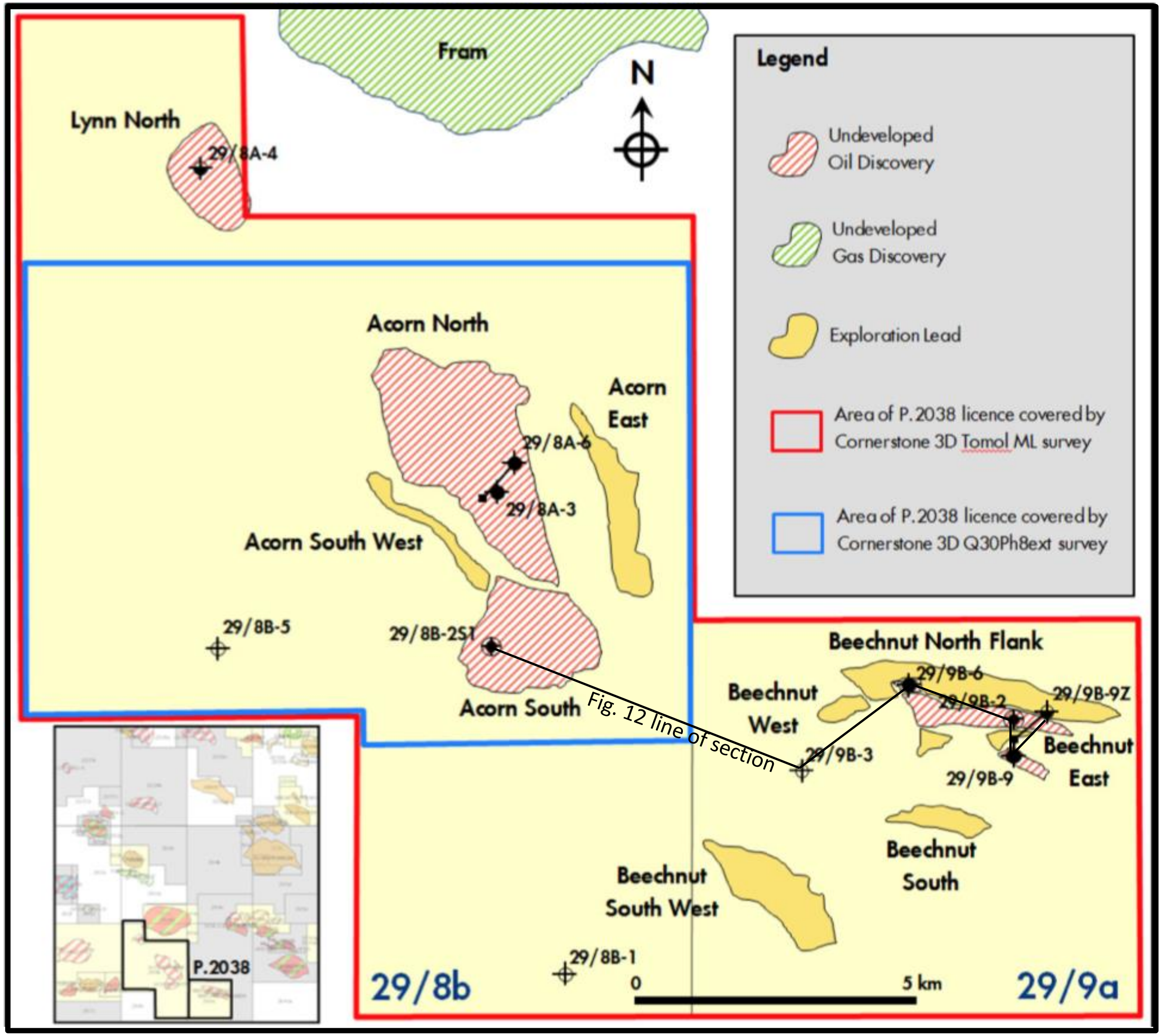
Acorn Field	*(Data and suggested Units)*	*(Author's explanatory comments)*
Trap		
Type	4-way dip closed	
Depth to crest	12,800 (ft TVDSS)	29/8a-6 penetrated a secondary crest about 1km south of the undrilled highest crest
Hydrocarbon contacts	13,216 (ft TVDSS)	Interpreted from FMT and test data range 13,100 ft to 13,250 ft
Maximum oil column thickness	416 (ft)	
Maximum gas column thickness	Not applicable (ft)	
Main Pay Zone		
Formation	Skagerrak Formation	Upper Jurassic Fulmar Formation is present in Acorn South
Age	Triassic	
Depositional setting	Terrestrial, ephemeral fluvial system	Channel belt sandstones are main reservoir
Gross/net thickness	max thickness 617 ft, net 205 ft	In oil and water columns
Average porosity (range)	16% (15-23%)	Data range for all facies in both wells

Average net:gross ratio	0.57	
Cutoff for net reservoir	10.6%	Porosity cut-off used
Average permeability (range)	Arithmetic 21 mD, geometric 8.4 mD (4.1-105 mD)	Range are averages for best and poorest reservoir facies
Average hydrocarbon saturation	53%	
Productivity index range	1-2 bbl/day/psi	
Hydrocarbons		
Oil gravity	35 (°API)	
Oil properties		
Bubble point (oil) Dew point (condensate)	Not reported	
Gas/Oil Ratio or Condensate/Gas Ratio	Not reported	Reported to have low GOR in relinquishment report
Formation Volume Factor (oil)	Not reported	
Gas gravity	n/a	
Gas Expansion Factor	n/a	
Formation Water		
Salinity	170,000-200,000-250,000 (ppm NaCl equiv.)	
Resistivity	0.012 ohm-m at 160 °C	
Pressure gradient - water	0.43 psi ft^{-1}	For salinity 200,000 ppm NaCl equivalent
Reservoir Conditions		
Temperature	160 (°C)	320 °F
Initial pressure	10,997 (psia at 13,200 ft TVDSS)	
Hydrocarbon pressure gradient - oil	0.33 (psi/ft)	
Hydrocarbon pressure gradient - gas	(psi/ft)	
Field Size		
Area	10.5 (km^2)	Approximate area based on digitizing map in Ventures, 2010
Gross Rock Volume	Not reported (ac-ft)	
STOOIP	100 (mmbbl) Triassic 13 (mmbbl) Jurassic	
Associated GIP	Not calculated (bcf)	
Non-associated GIP	Not calculated (bcf)	
Drive mechanism (primary, secondary)		
Recovery to date - oil	0 (mmbbl)	

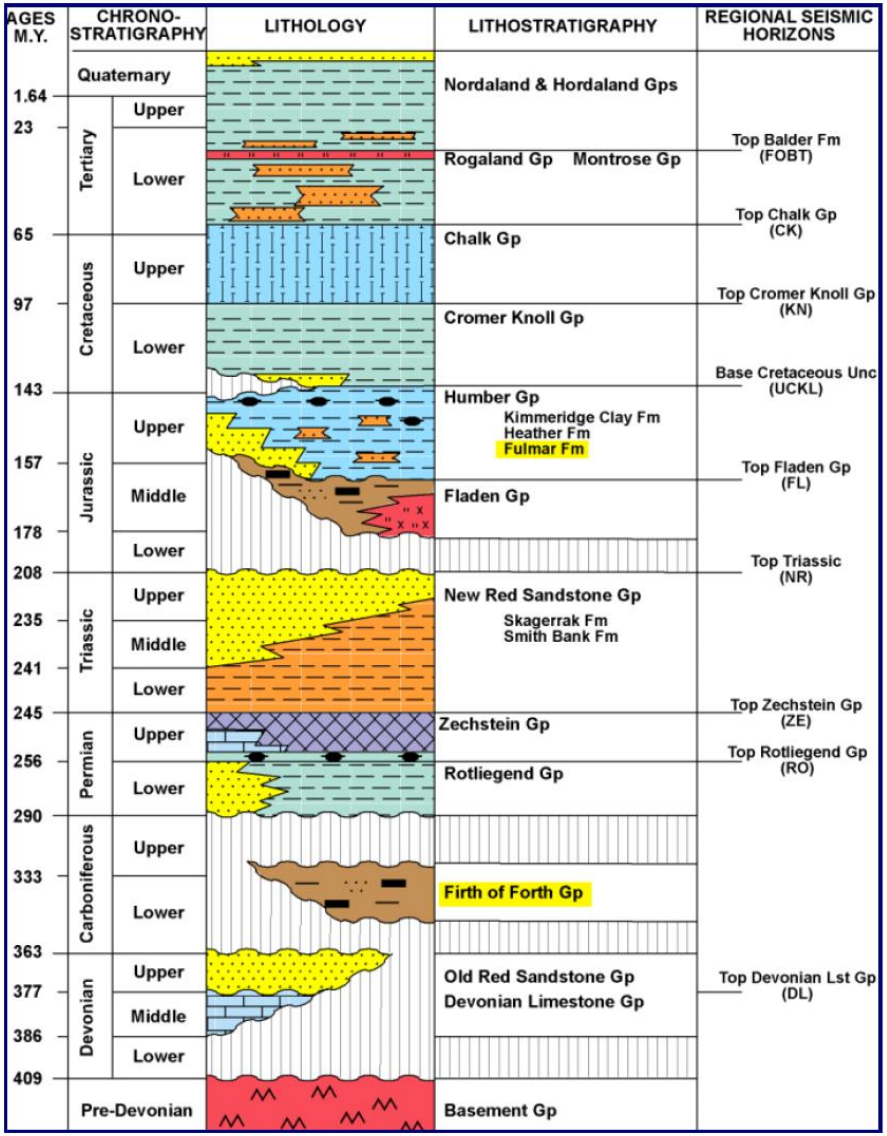
Recovery to date - gas	0 (bcf)	
Expected ultimate recovery factor/volume - oil	0 (%)/ 0 (mmbbl)	
Expected ultimate recovery factor/volume - gas	0 (%)/(bcf)	
Production		
Start-up date	undeveloped	
Number of Exploration/Appraisal Wells	1E/2A	
Number of Production Wells	0	
Number of Injection Wells	0	
Development scheme		
Plateau rates – oil/gas	0 bopd 0 mmcfgd	
Planned abandonment	*Undeveloped*	

Beechnut Field	*(Data and suggested Units)*	*(Author's explanatory comments)*
Trap		
Type	Faulted anticline	
Depth to crest	13,200 (ft TVDSS)	ODT in 29/9b-2 is in Lower Jurassic Gassum Formation
Hydrocarbon contacts	ODT 14,030 (ft TVDSS)	
Maximum oil column thickness	775 (ft)	Minimum oil column
Maximum gas column thickness	Not applicable (ft)	
Main Pay Zone		
Formation	Fulmar Formation	Minor oil column in Triassic Skagerrak
Age	Upper Jurassic	
Depositional setting	Shallow marine fringe around former Kimmeridgian structural highs	
Gross/net thickness	max thickness 70 ft	
Average porosity (range)	17.6% (11.1-18.3%)	
Average net:gross ratio	0.46	Range 0-0.92
Cutoff for net reservoir	10%	
Average permeability (range)	10 mD (0.01-200 mD)	From logs and consistent with DST data
Average hydrocarbon saturation	72%	
Productivity index range	Not reported	
Hydrocarbons		
Oil gravity	34.5-40.6 (°API)	
Oil properties		
Bubble point (oil) Dew point (condensate)	2500 psig	

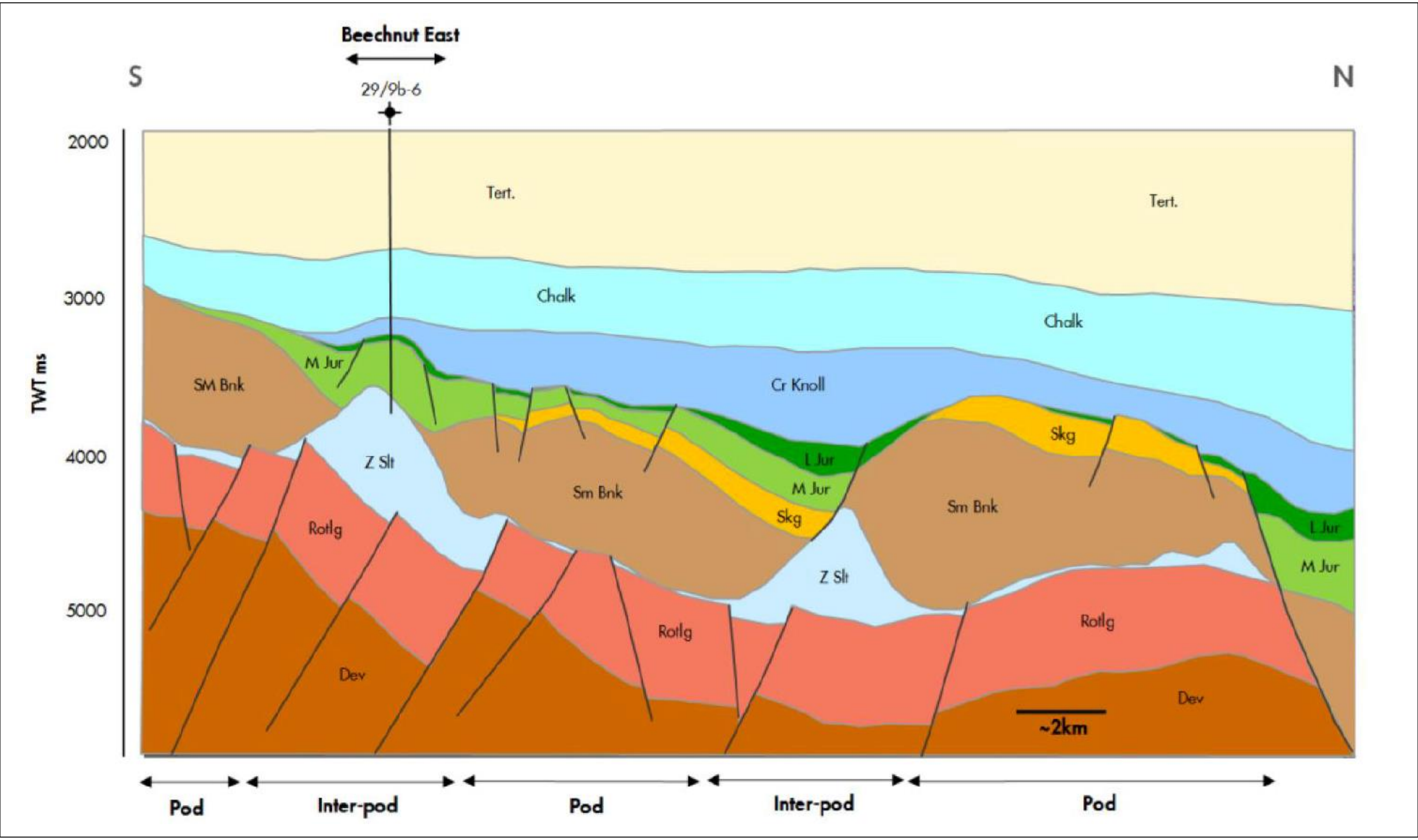
Gas/Oil Ratio or Condensate/Gas Ratio	699 scf/bbl	
Formation Volume Factor (oil)	1.35	
Gas gravity	n/a	
Gas Expansion Factor	n/a	
Formation Water		
Salinity	200,000 (ppm NaCl equiv.)	
Resistivity	0.012 ohm-m at 160 °C	
Pressure gradient - water	psi ft^{-1}	Water not encountered
Reservoir Conditions		
Temperature	157 (°C)	315 °F
Initial pressure	11,040 (psia at 13,800 ft TVDSS)	
Hydrocarbon pressure gradient - oil	0.289-0.306 (psi/ft)	
Hydrocarbon pressure gradient - gas	(psi/ft)	
Field Size		
Area	1 (proven) -3.5 (km^2)	Approximate proven area based on digitizing map in Shell, 2015
Gross Rock Volume	Not reported (ac-ft)	
STOOIP	7-52 (mmbbl)	
Associated GIP	Not calculated (bcf)	
Non-associated GIP	Not calculated (bcf)	
Drive mechanism (primary, secondary)		
Recovery to date - oil	0 (mmbbl)	
Recovery to date - gas	0 (bcf)	
Expected ultimate recovery factor/volume - oil	0 (%)/ 0 (mmbbl)	
Expected ultimate recovery factor/volume - gas	0 (%)/(bcf)	
Production		
Start-up date	undeveloped	
Number of Exploration/Appraisal Wells	1E/3A	Well 29/9b-9 and 9z counted as 2 wells as they penetrated different parts of the field
Number of Production Wells	0	
Number of Injection Wells	0	
Development scheme		
Plateau rates – oil/gas	0 bopd 0 mmcfgd	
Planned abandonment	*Undeveloped*	



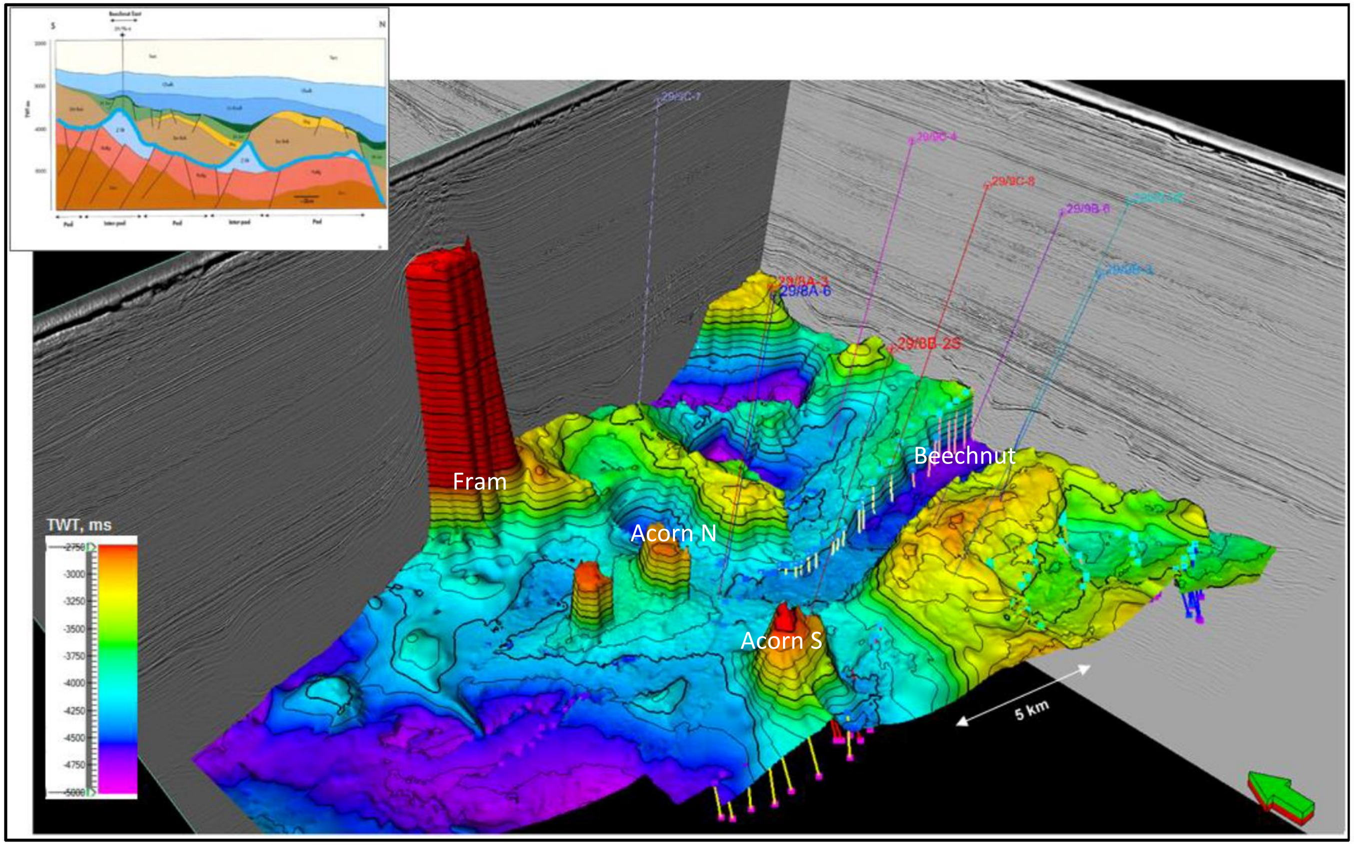
Acorn Beechnut Figure 1



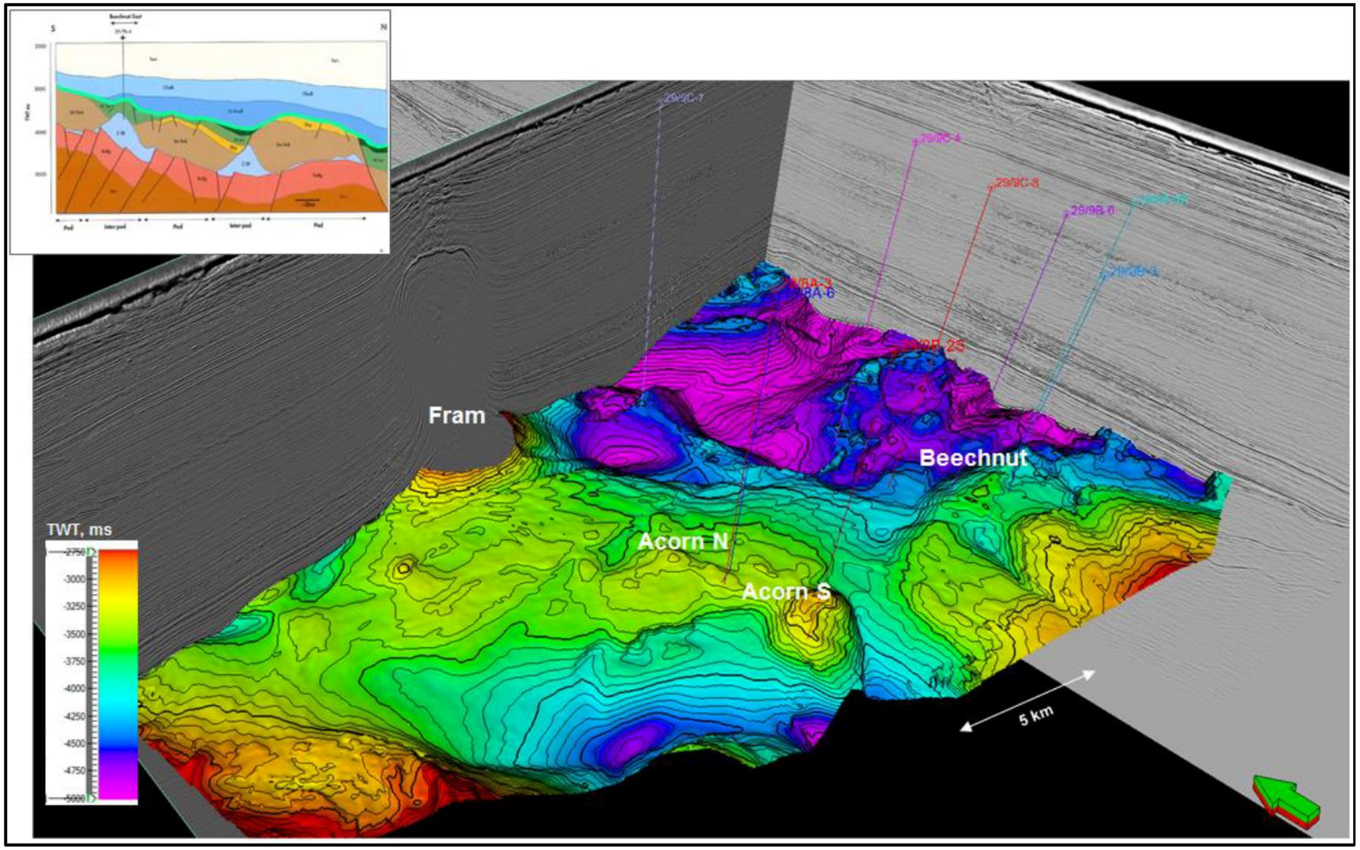
Acorn Beechnut Figure 2



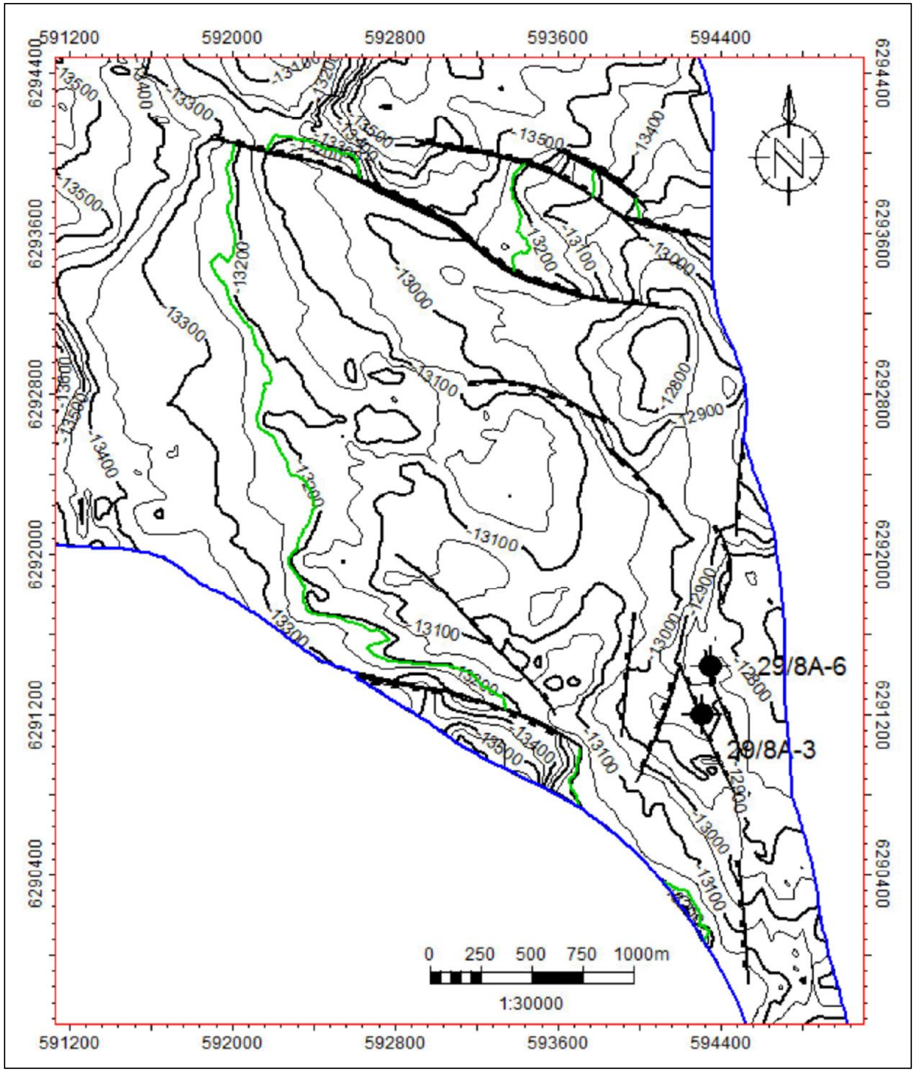
Acorn Beechnut Figure 3



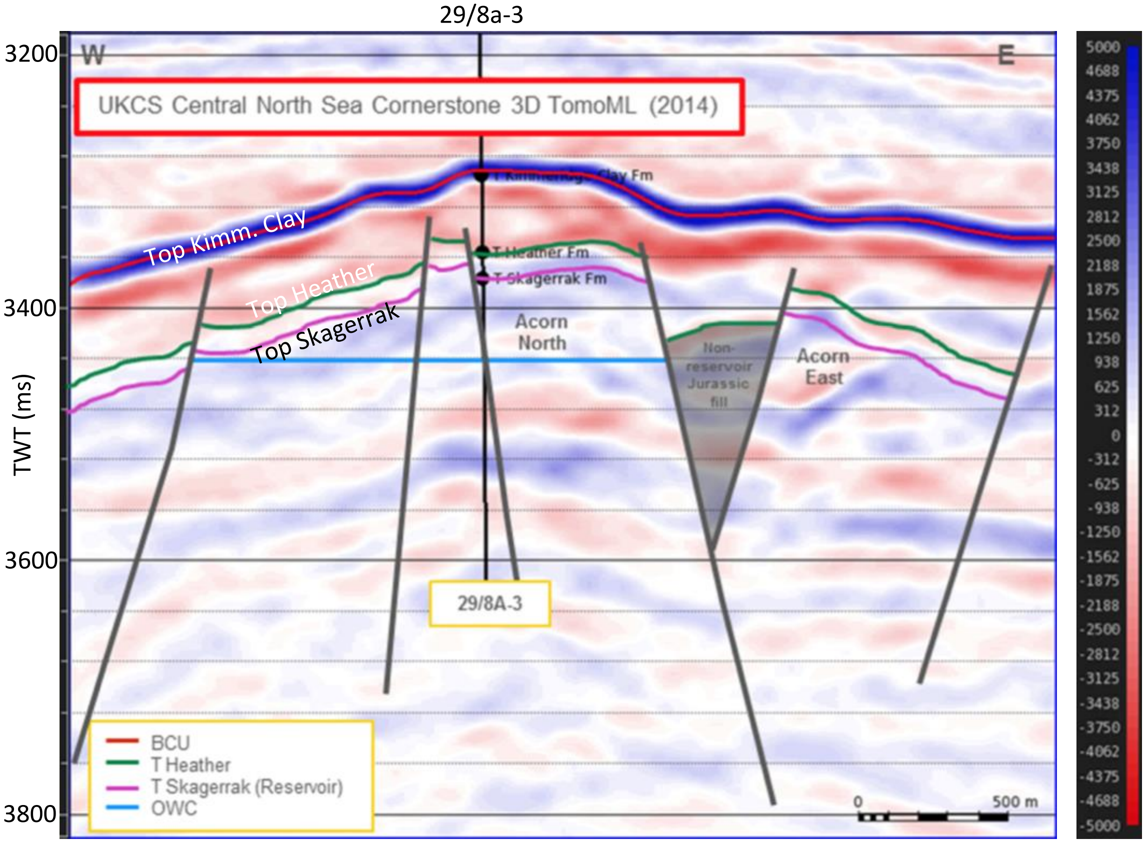
Acorn Beechnut Figure 4



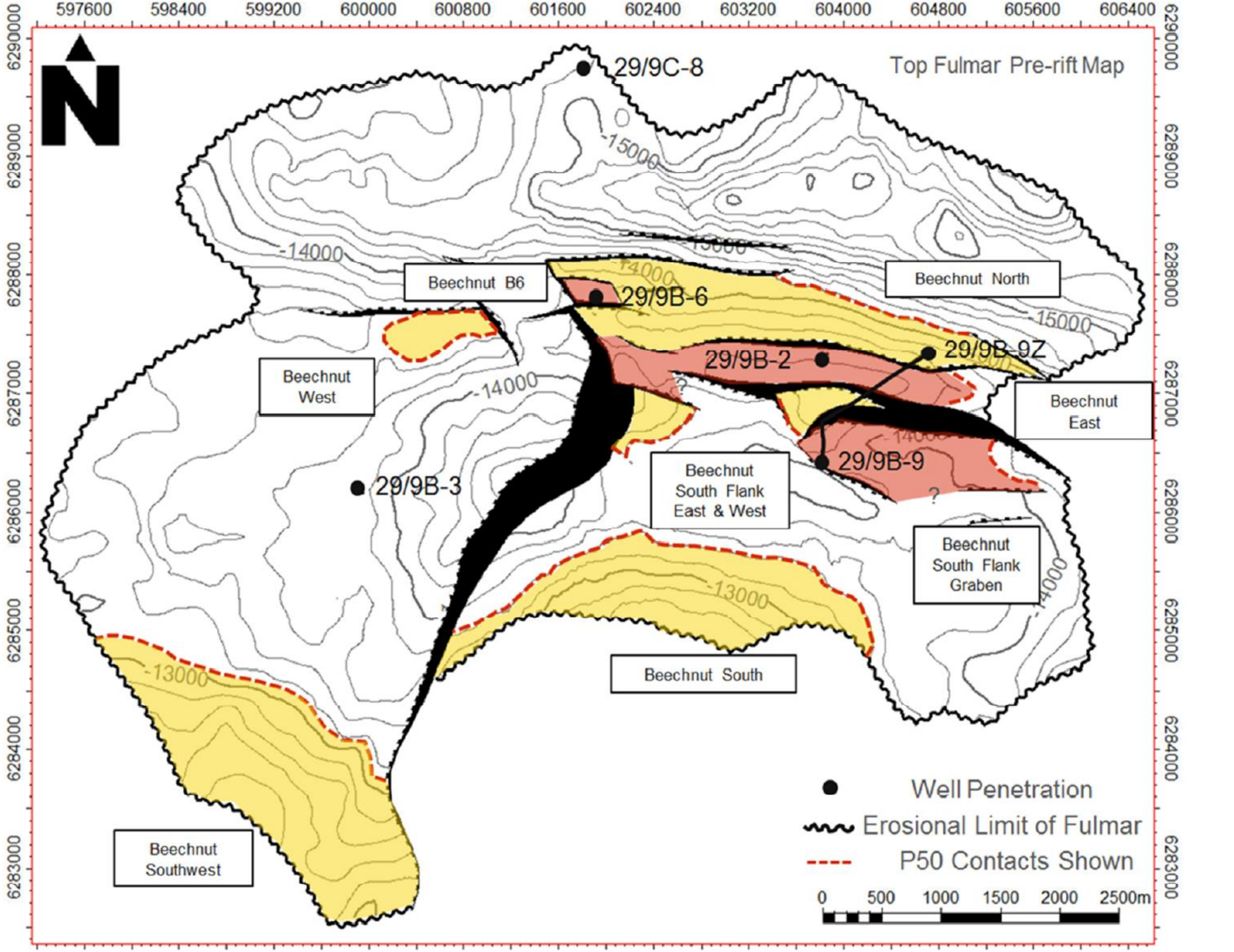
Acorn Beechnut Figure 5



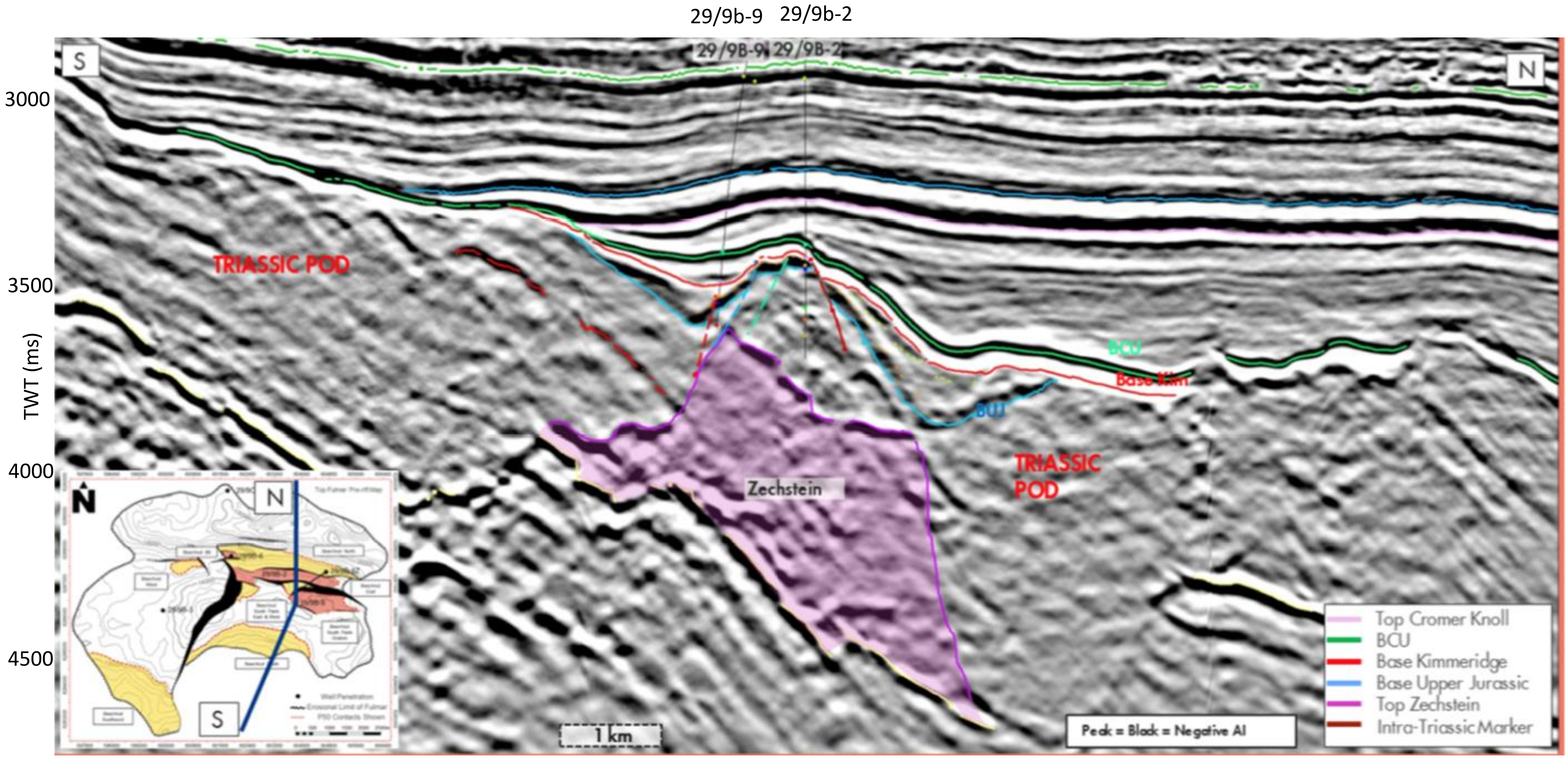
Acorn Beechnut Figure 6



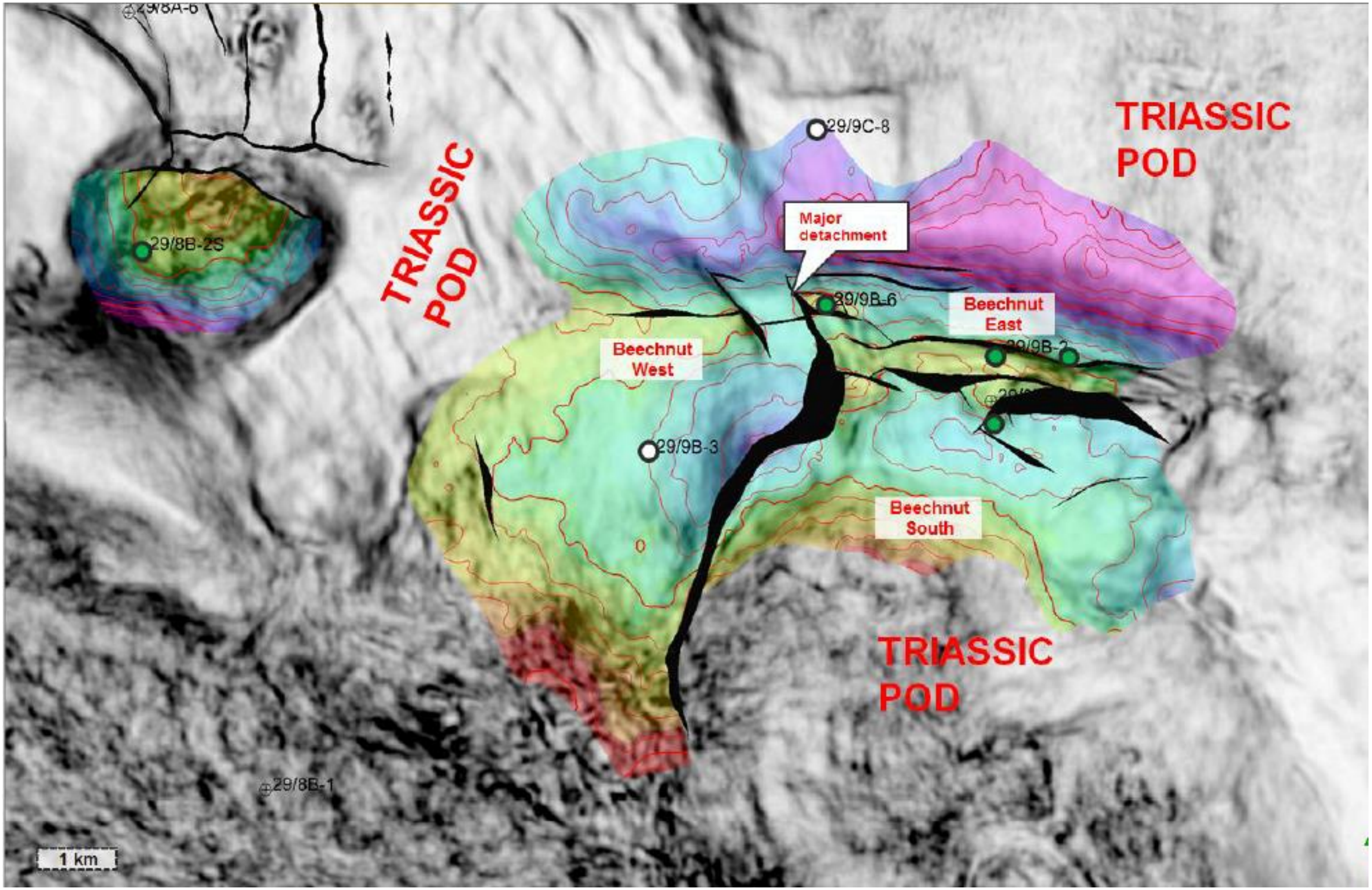
Acorn Beechnut Figure 7



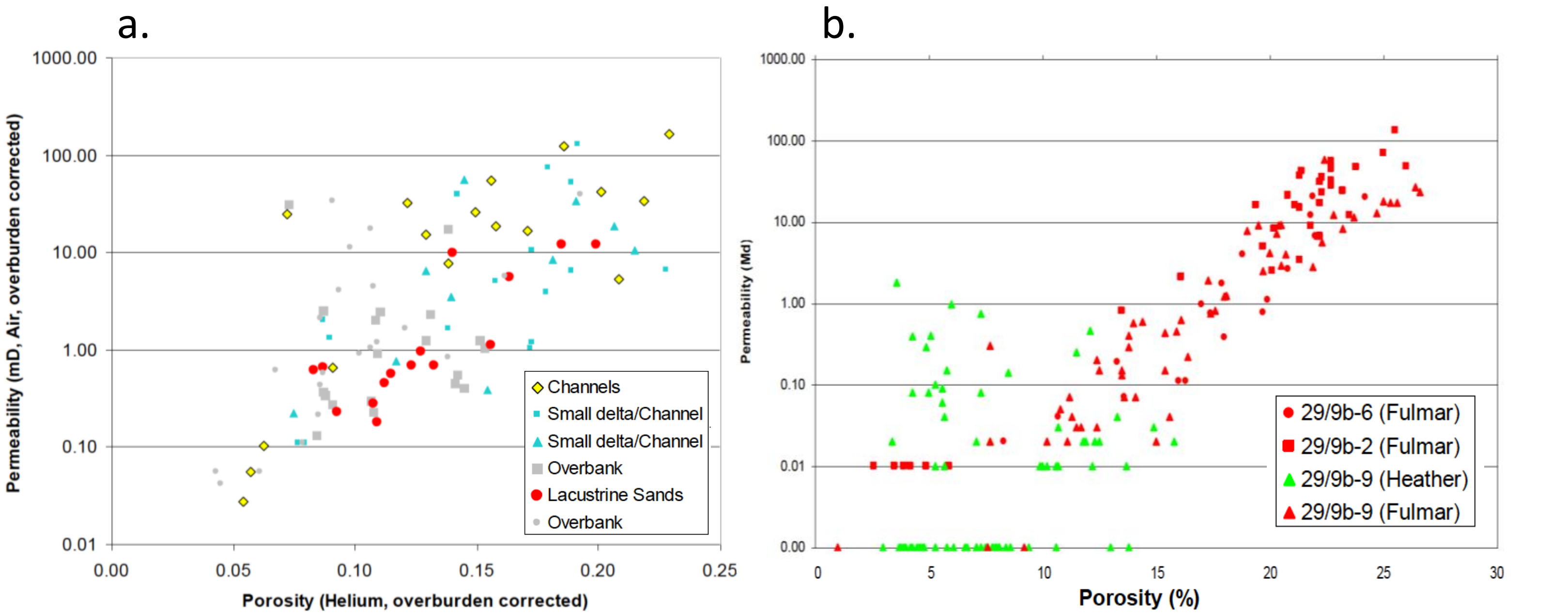
Acorn Beechnut Figure 8



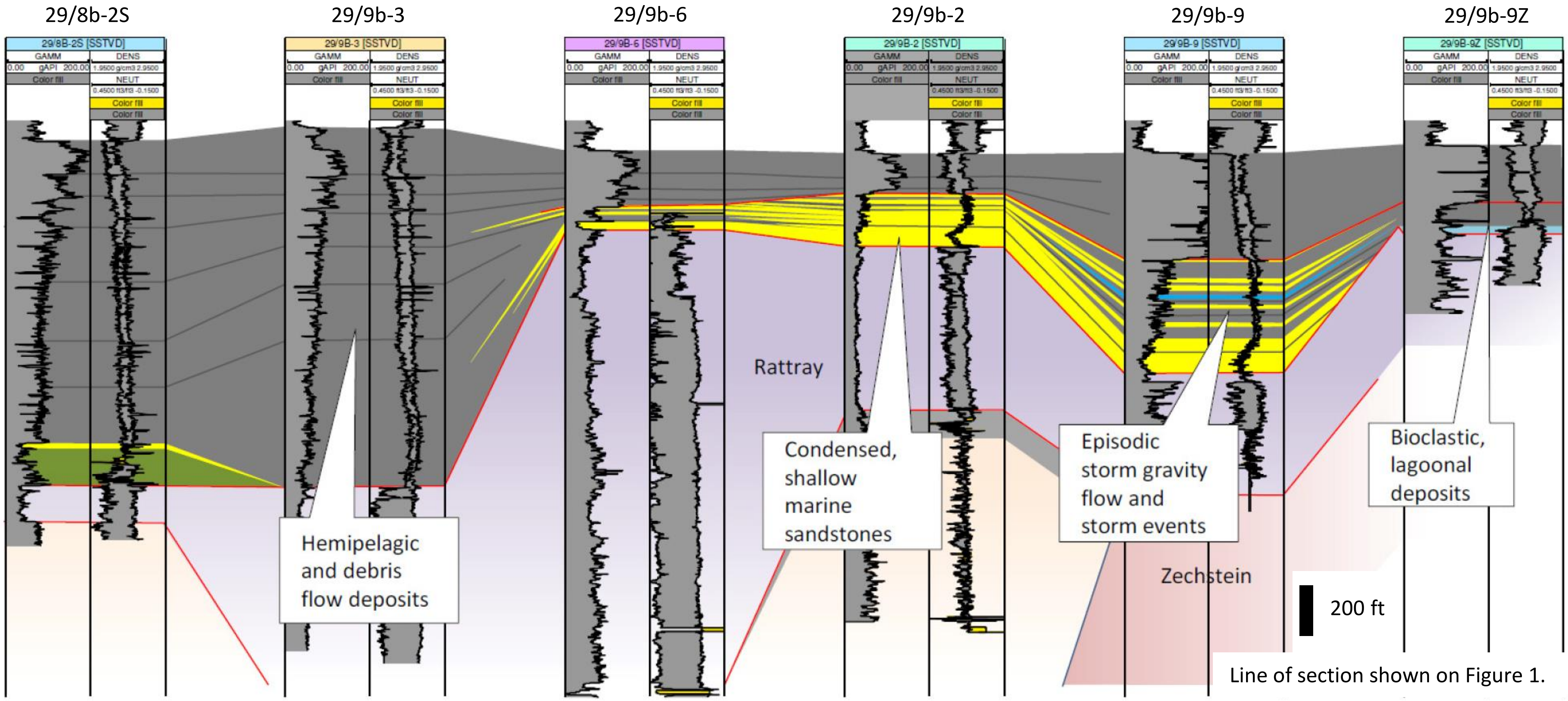
Acorn Beechnut Figure 9



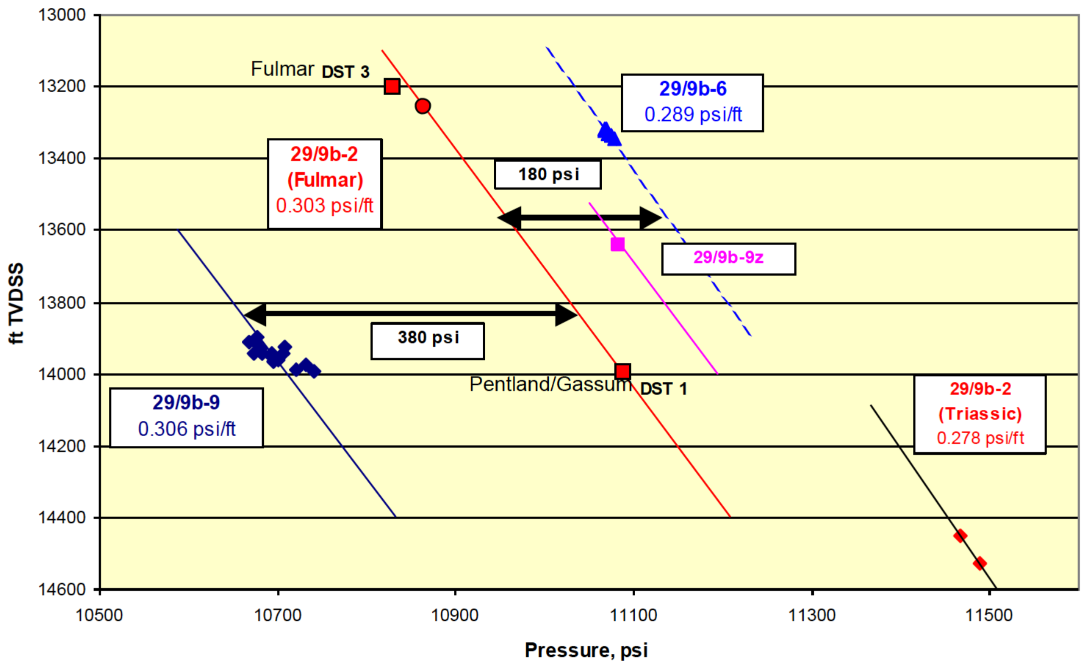
Acorn Beechnut Figure 10



Acorn Beechnut Figure 11



Acorn Beechnut Figure 12



Acorn Beechnut Figure 13